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(54) EXHAUST AIR HEAT PUMP APPARATUS AND METHOD OF PROCESSING EXHAUST AIR

(57) The invention relates to an exhaust air heat pump apparatus (10) and method of processing exhaust air of buildings. The present apparatus comprises a first inlet channel (13) for exhaust indoor air, an outlet channel (15) for discharge air, and a heat pump unit (11) comprising an air intake connected to the first inlet channel (13) and air output connected to the outlet channel (15), the heat pump unit (11) being capable of recovering heat from or transferring heat to air provided to said air intake, whereby said discharge air is produced at the air output. According to the invention, there are further provided a second inlet channel (18) for outdoor air, the second inlet channel (18) being connected to the air intake of the heat pump unit (11) and a recirculation channel (17) capable of recirculating part of air at the output of the heat pump unit (11) back to the air intake of the heat pump unit (11). The apparatus is adapted to mix the outdoor air, the recirculated air or both of them with the exhaust indoor air before feeding to the heat pump unit (11). The invention allows for optimization of heat pump efficiency in varying conditions.

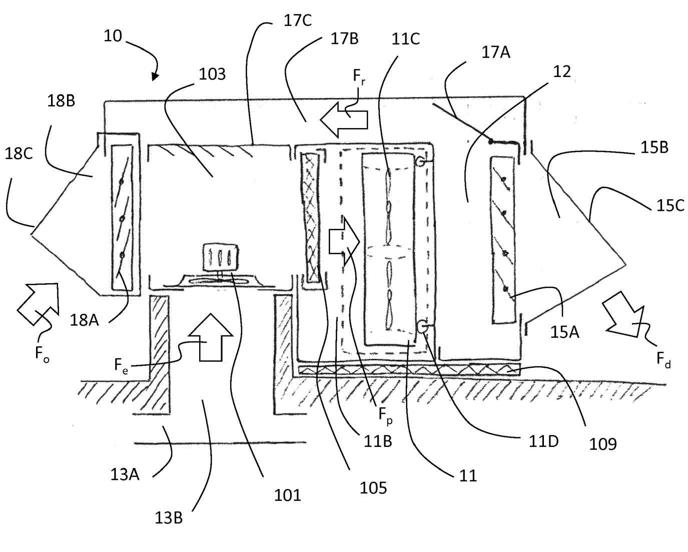

Fig. 2A

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Description

Field of the Invention

[0001] The invention relates to exhaust air heat pump (EAHP) technology. In particular, the invention relates to EAHP apparatuses and exhaust air heat recovery methods. EAHP apparatuses comprise an inlet channel for exhaust indoor air, an outlet channel for discharge air, and a heat pump unit for recovering heat from the exhaust indoor air.

Background of the Invention

[0002] Exhaust air heat pump systems are used to recover heat from indoor air that is exhausted and discharged from a building through ventilation. Modem efficient systems are active systems, which employ a heat pump that is able to transfer heat from the indoor air back to the building, improving energy efficiency of the system. In centralized air-to-air heat recovery ventilation (HRV) or air conditioning systems, the heat is transferred to fresh replacement air taken in by the HRV system and delivered to the building. In decentralized replacement air exhaust air heat pump systems the heat is often transferred to a liquid-state heating medium used e.g. in domestic hot water (DHW) and/or central heating system of the building. In decentralized replacement air systems, there are other replacement air channels in the building, such as fresh air channels on walls or windows of the building.

[0003] Optimizing the function of an active heat recovery apparatus is a complex task. One example of centralized HRV systems is presented in WO 2011/077007, which discloses one related apparatus with an arrangement to enhance its function. The apparatus comprises an exhaust air duct, a discharge duct, a fresh air duct and an inlet air duct. There is also provided a first evaporator-condenser unit adapted to the discharge air duct and a second evaporator-condenser unit adapted to the inlet air duct. There is also a bypass channel and flow control means between the fresh air duct and the discharge air duct, prior to the first evaporator-condenser unit in the flow direction of the discharge air duct and prior to the second evaporator-condenser unit in the flow direction of the inlet air duct. The bypass channel and flow control means are adapted to pass fresh air from the fresh air duct to the discharge air duct in order to enhance the function of the evaporator-condenser unit.

[0004] Particular control and optimization challenges are faced in decentralized replacement air EAHP systems, because the flow of replacement air to the building is not under direct control of the HRV system but the amount of indoor air flowing through the heat pump must be high enough for heat to be efficiently recovered. For example, in many-apartment houses with a common EAHP, adjusting the air flow rates in replacement and/or exhaust air channels in a single apartment affects the balance of the system and also the ventilation of other apartments in the building. This can lead to situations where the EAHP is far from its optimal point of operation and/or some apartments are facing problems relating to indoor air quality, temperature or ventilation. Another problem relating to decentralized replacement air EAHP systems relates to their relatively low coefficient of performance (COP) in some situations.

[0005] Thus, there is a need for improved EAHP systems.

Summary of the Invention

[0006] It is an aim of the invention to provide a novel exhaust air heat pump apparatus with improved controllability and/or efficiency. A particular aim is to provide an EAHP apparatus, which has improved controllability and/or efficiency when installed in many-apartment buildings having decentralized replacement air intake system. It is also an aim to provide a related method for recovering energy in ventilation systems.

[0007] According to one aspect, the invention provides an exhaust air pump apparatus comprising a first inlet channel for exhaust indoor air, an outlet channel for discharge air, and a heat pump unit comprising an air intake connected to the first inlet channel and air output connected to the outlet channel, the heat pump unit being capable of recovering heat from air provided to said air intake, whereby the discharge air is produced at the air output. The apparatus further comprises a recirculation channel capable of conveying part of air at the output of the heat pump back to the air intake of the heat pump unit mixed with the exhaust indoor air and a second inlet channel for feeding outside air to the inlet of the heap pump mixed with the exhaust indoor air, and optionally also with the recirculated air. Thus, part of the air fed to the heat pump for heat recovery comprises non-recirculated, i.e., "fresh" exhaust air and part of the air comprises recirculated air, outdoor air, or both.

[0008] According to another aspect, the heat pump unit is adapted, instead of recovering heat from the mixed air using the heat pump, to cool the building by transferring heat from a heat reservoir of the building to the mixed air provided to the heat pump in order to cool the heat reservoir.

[0009] The present exhaust air process comprises recovering heat from exhaust air of a building or transferring heat out of the building together with exhaust air. Thus, the method comprises exhausting air from the building to an air mixing zone and feeding air from the air mixing zone through a heat pump comprising an air intake and an air output and being adapted to recover heat from or transfer heat to air provided to the intake and to provide secondary air, i.e. cooled or heated air, respectively, at the output of the heat pump. A portion of the secondary air is recirculated back to the mixing zone and/or outdoor air is fed to the mixing zone, where the recirculated air and/or outdoor air is mixed with the exhausted air before feeding to the air intake of the heat pump.

[0010] More specifically, the invention is characterized by what is stated in the independent claims.

[0011] The invention offers significant advantages. The possibility to recirculate air as well as to intake outdoor air increases the control possibilities of the apparatus, as not only the exhaust air can be used as a heat source but also the outdoor air and air having passed through the heat pump. In addition, the apparatus is more immune to varying ventilation conditions of the building. For example, if residents in some part of the building close their exhaust or replacement air valves, the missing air in the EAHP apparatus can be replaced with recirculated air and/or outdoor air without affecting other parts of the building. In addition, as heat pumps require a certain amount of air flowing through them in order to operate efficiently, in some conditions, it may be beneficial to recirculate part of air back to the heat pump and/or to add outdoor air to the air flow passing the heat pump to maintain high COP, even though the recirculated air, and often also outdoor air, is cooler than the "fresh" exhaust air. The amount of recirculated air and/or outdoor air can be e.g. 1...50% of the total volume flow passing the heat pump unit. The possibility to choose between recirculated air and outdoor air, or to use both of these simultaneously, is beneficial as it makes it possible to find optimal mode of driving of the apparatus in different outdoor temperatures, for example.

[0012] The dependent claims are directed to selected embodiments of the invention.

[0013] According to one embodiment, the apparatus comprises means for adjusting mixing ratio of exhaust indoor air, outdoor air and recirculated air. Typically, the apparatus can be driven in a mode of operation where a significant portion, in particular at least 25%, typically at least 50%, such as 50-95% of mixed air comprises exhaust indoor air, in terms of volume flow. The rest comprises outdoor air, recirculated air, or both.

[0014] According to one embodiment, the recirculation channel comprises a first adjustable valve (recirculation valve) for controlling the amount of air recirculated to the air intake of the heat pump unit. According to one embodiment, the second inlet channel for outdoor air comprises a second adjustable valve (outdoor air valve) for controlling the amount of outdoor air provided to intake of the heat pump unit through the second inlet channel. There may also be an adjustable discharge valve in the discharge channel of the apparatus, whereby the positions of the recirculation valve, outdoor air valve and discharge valve together determine the mixing ratio of the mixed air flow fed to the heat pump.

[0015] In some embodiments, there is provided a mixing zone, such as a mixing chamber, upstream of the heat pump. The mixing zone is adapted to mix the exhaust indoor air with the recirculated discharge air and/or the outdoor air before feeding to the intake of the heat pump. The proportions of air to be mixed are dependent on the positions of the outdoor air valve and the recirculation valve, and optionally the discharge valve.

[0016] Embodiments with both adjustable recirculation channel and adjustable outdoor air inlet channel, and a control system for adjusting them, are particularly advantageous. They allow for adjusting the flows in varying ambient air temperature conditions and ventilation configurations, and therefore optimization of COP of the heat pump.

[0017] According to one embodiment, there are provided one or more temperature and/or air flow sensors within the apparatus and a control unit adapted to control the adjustable valves of the apparatus based on measurement data provided by the sensors. The control unit may be adapted to control the valves such that in a first mode of operation at least a portion of air provided to the mixing zone comprises recirculated air and in a second mode of operation at least a portion of air provided to the mixing zone comprises outdoor air. In typical configurations, at least a portion of the air provided to mixing zone comprises non-recirculated exhaust air.

[0018] For example, the control unit may be adapted to control the flows of recirculated air and outdoor air to the mixing zone based on temperature and/or air flow measurements such that a significant portion, preferably at least 25%, such as 25 ... 95%, in particular 50...95% of air in the mixing zone is air exhausted directly from the building, and the remaining portion is recirculated air and/or outdoor air in proportion 0:100...100:0.

[0019] According to one embodiment, the mixing zone comprises at least one mesh of metal through which the air is adapted to flow. This evens out temperature differences within the flow and improves the energy efficiency of the heat pump.

[0020] According to one embodiment, the apparatus is a decentralized replacement air exhaust air heat pump apparatus, wherein the heat pump unit is adapted to recover heat to or transfer heat from a liquid circuit connectable to heat distribution system of a building. Thus, there are no replacement air channels in the apparatus that would be suitable for conducting fresh outdoor air to the building. Instead of that, the replacement air channels form a separate functional system in the building. In particular, the replacement air channels can be distributed on outer walls and/or windows of different rooms of the building.

[0021] According to one embodiment, the heat pump unit comprises a single heat pump. There may also be a cascade of two of more heat pumps, whereby said recirculation channel is arranged to convey air from air output of the last heat pump to air input of the single heat pump or the first heat pump of the cascade.

[0022] According to one embodiment, the apparatus comprises an exhaust fan adapted to transfer the exhaust air from the building to the mixing zone.

[0023] According to one embodiment, the heat pump unit is provided with one or more heat pump fans for conveying air through the heat pump unit, and wherein said conveying of air through the air recirculation channel is adapted to occur solely due to air pressure caused by said heat pump fan(s). Flow of recirculated air can be adjusted by means of a valve in the recirculation channel in the presence of said pressure. This makes the apparatus very cost effective and maintenance-free.

[0024] In some embodiments, there are only two fans or fan groups in the apparatus, i.e., an exhaust air fan (group) and heat pump fan (group), using which all the air flows are made to occur as determined by valves in respective channels.

[0025] According to one embodiment, heat is recovered by the heat pump to a central heating water and/or domestic water reservoir of the building.

[0026] In a typical installation environment, the exhausting comprises collecting air from at least ten different rooms of the building, and providing at least part of replacement air to said room via decentralized replacement air channels, i.e. outside the present apparatus. The present invention is most beneficial in many-apartment houses with at least 10 apartments, such as 10 - 100 apartments, a centralized exhaust ventilation system, and decentralized replacement air system (many replacement air intake points). In such buildings, the ventilation conditions are continuously changing due to changing of ambient conditions and actions of the residents of the building, whereby improved controllability of ventilation and heat recovery is needed without sacrificing performance too much.

[0027] Next, embodiments of the invention and advantages thereof are discussed in more detail with reference to the attached drawings.

Brief Description of the Drawings

[0028]

Fig. 1 shows schematically an AEHP apparatus according to one embodiment of the invention.

Figs. 2A and 2B show in more detail the construction of an EAHP apparatus as side and top views, respectively, according to one embodiment.

Figs. 3A and 3B illustrate in two different views a temperature evening assembly.

Fig. 4 depicts a building provided with an EAHP apparatus according to one embodiment of the invention.

Fig. 5 illustrates a heat recovery method according to one embodiment of the invention.

Fig. 6 shows an alternative EAHP apparatus, containing an additional heat transfer for efficient flow control and heat recovery.

Detailed Description of Embodiments

[0029] In the following description, embodiments of exhaust air heat pump apparatus suitable for recovering heat is described. However, the same apparatus can be used for cooling purposes, by providing it with means for operating the heat pump in an opposite way so that the heat pump, instead of transferring heat from the mixed air to a liquid circuit, for example, transfers heat from the liquid circuit to the mixed air. In both cases, optimization of heat pump efficiency in varying conditions is possible.

[0030] With reference to Fig. 1, the exhaust air heat pump apparatus 10 comprises a heat pump 11, which forms the heat recovery core of the apparatus 10. There is provided a first inlet channel 13 for exhaust indoor air flow F_e. The inlet channel 13 is connected to a mixing zone 22. The mixing zone 22 is further connected to air intake of the heat pump 11 for providing a pump flow F_p through the pump 11. In the heat pump 11, a heat flow 19 is formed from pump flow F_p to a liquid circuit, comprising a liquid inlet 14 and liquid outlet 16. There is also provided an outlet channel 15 to outdoors for discharge air flow F_d passing the heat pump. However, there is provided a recirculation channel 17 for directing part of the air passing the heat pump 11, i.e. recirculation flow F_r, back to the mixing zone 22. Thus, when the recirculation channel 17 is in use, the pump flow F_p is a sum of exhaust air flow F_e and recirculation flow F_r.

[0031] There is also provided a second inlet channel 18 for outdoor air flow F_o. Also this inlet is connected to the mixing zone 22, adding a third potential sum component to the pump flow F_p, namely the outdoor flow F_o.

[0032] The apparatus can be used in different modes of operation. In one mode, the pump flow F_p essentially consists of the exhaust flow F_e, recirculation flow F_r and outdoor air flow F_o in a chosen mixing ratio. In another mode, the pump flow F_p essentially consists of the exhaust flow F_e and recirculation flow F_r in a chosen mixing ratio. In still another mode, the pump flow F_p essentially consists of the exhaust flow F_e and outdoor air flow F_o in a chosen mixing ratio. In all cases, the exhaust flow F_e preferably forms at least 25%, in particular at least 50% of the total pump flow F_p in terms of volume flow.

[0033] The mixing zone 22 in front of the heat pump 11 is used to even out temperature and pressure differences in the various flows such that the heat pump flow F_p is as homogeneous as possible and the pump 11 will operate optimally. The mixing zone 22 may comprise a chamber with a volume sufficient for the air flows to mix. In addition, there may be provided additional temperature evening means, such as a stack of metal wires or meshes that facilitate evening out of temperature differences.

[0034] According to one embodiment, the mixing zone is adapted to even out the temperature such that in the mixed air flow fed to the heat pump temperature unevenness, i.e. maximum temperature difference between different cross-sectional points of the flow, is at maximum half, in particular at maximum a quarter, of the maximum difference between temperatures of the incoming flows.

[0035] Figs. 2A and 2B show an exemplary structure of the exhaust air heat pump apparatus 10 installed on a roof of a building. In the exemplary configuration, an insulation layer 109 is provided between the roof and the apparatus 10 for reducing transfer of vibrations. The exhaust air is provided through ventilation channels 13A from different parts of the building to a common collector chamber 13B. An exhaust fan 101 causes an underpressure that causes the exhaust air to enter a mixing chamber 103 of the apparatus. Between the mixing chamber 103 and the heat pump 11, there is provided a temperature evening assembly 105 through which the air flow passes on its way to an intake chamber 11B of the heat pump 11. One or more heat pump fans 11C cause the air to pass the heat pump. The heat pump flow channel may secured with one or more seal elements 11D that ensure that all air goes through heat transfer zone (not specifically shown) of the heat pump 11. The heat pump 11 comprises also connectors 111 for liquid circuit to which the heat is recovered.

[0036] Air exiting the heat pump 11 is directed to a circulation chamber 12 from which there are two exits. One of the exist leads to the ambient air space through an adjustable discharge valve 15A, optionally via a discharge chamber 15B. The discharge chamber 15B is formed by a weather shield 15C preventing water or snow from entering the apparatus. The other exit leads to a recirculation channel 17B through an adjustable recirculation valve 17A.

[0037] The recirculation channel 17B leads to the mixing chamber 103 through optional recirculation air grate 17C. In the described way, the recirculation flow F_r is controlled by the positions of the valves 15A, 17A without any additional fans. Although herein presented as to separate components, valves 15A, 17A can also be understood and, if desired, also physically implemented as a single discharge/recirculation valve.

[0038] The exemplary apparatus comprises also the possibility to mix fresh outdoor air to the pump flow F_p. For this purpose, there is provided an outdoor air intake valve 18A, which, when open, allows ambient outdoor air flow F_o to enter the mixing chamber 103 due to pressure caused by the pump fan 11C. The ambient air is taken from an outdoor air intake chamber 18B defined by a weather shield 18C. In the mixing chamber 103, the oudoor air is mixed with the exhaust air and recirculated air before feeding to the intake chamber 11B of the heat pump 11. The intake air temperature of the heat pump is thus determined by the temperatures and magnitudes of the exhaust, recirculation and oudoor air flows.

[0039] There may be provided a control unit (not shown) functionally connected to the valves 15A, 17A, 18A. The control unit can be configured to drive the apparatus selectively into a first mode of operation, where only outdoor air is mixed with exhaust air, into a second mode of operation, where only recirculated air is mixed with exhaust air, and optionally into a third mode of operation, where both outdoor air and recirculated are mixed with exhaust air before feeding to the heat pump.

[0040] There may be provided one or more temperature sensors (not shown) in the collector ventilation channel 43 (for measuring the temperature of the exhaust air flow), recirculation channel 17B (recirculation flow), outdoor air intake chamber 18B (outdoor flow) and/or the heat pump unit (heat pump flow). The sensors are functionally connected to the control unit to provide input data for a control algorithm running therein.

[0041] The heat pump may comprise any exhaust air heat pump known *per se,* preferably configured to recover heat form air to a liquid medium.

[0042] Figs. 3A and 3B show an exemplary temperature evening element 105, which comprises stack of a plurality, in this case four, metal meshes, such as aluminum meshes that are thermally well conductive. This kind of an element 105 is efficient and easy to keep clean by e.g. water jet, and allows for a filterless apparatus design.

[0043] Valves 15A, 17A, 18A may comprise plate valves driven by motors controlled by a control unit (not shown).

[0044] Fig. 4 shows a many-apartment building 41 with the present apparatus 40 installed on top of it. The building comprises ventilation channels 42 in each apartment and/or room 49 thereof, and a collector ventilation channel 43, that are designed to provide an exhaust air flow F_e which is directed to the exhaust air channel of the apparatus 40 operating in the way described above. Replacement air flows to the apartments/rooms 49 of the building are denoted with numeral 48.

[0045] Fig. 5 illustrates the present heat recovery method. The heat recovery process is started in step. After that, magnitudes of air flows and/or temperatures thereof are measured and input to a monitoring and control system in step 52. The monitoring and control system runs an algorithm based on which the proportions of recirculation air flow F_r and the outdoor air flow F_o of the total pump flow F_p are adjusted using suitable control electronics and mechanics.

[0046] Fig. 6 shows a variation of the apparatus shown in Figs 2A and 2B. The apparatus comprises the same basic components, but has a heat transfer element 606 provided in or in front of the mixing chamber 603.

[0047] The heat transfer element 606 is placed in front of the heat pump unit so as to transfer heat between outdoor air, recirculated air, exhaust indoor air, and optionally outdoor air, before mixing them for feeding to the heat pump unit. In addition, the heat transfer element 606 may also comprise a branch outlet for the recirculated air for drawing not all of the recirculated air to back the heat pump but a part of it to the environment through the heat transfer element 606.

[0048] The heat transfer element 606 has an inlet for the exhaust air flow F_e, an inlet for recirculated air flow F_r, and, optionally, for outdoor intake air flow F_o. In addition, it comprises at least one outlet through which the exhaust air flow F_e, an inlet for recirculated air flow F_r, and, optionally, the outdoor intake air flow F_o having passed the heat transfer element is conducted towards the heat pump unit as heat pump air flow F_p.

[0049] The heat transfer element 606 may contain internal flow channels, through which the flows run and between which temperature differences even out. Thus, the heat transfer cube may supplement or entirely replace the temperature evening element 105 shown in in Figs. 2A and 2B. In addition to evening the temperatures, the element 606 may be configured to affect the magnitudes of the various flows running therein so as to fine-tune the operation of the apparatus.

[0050] According to one embodiment, the heat transfer element 606 comprises an additional outlet for recirculation outlet flow F_{ro}, which is therefor arranged to bypass the heat pump directly to the outside. The magnitude of the recirculation outlet flow F_{ro} can generally equal to 0 ... F_r. Preferably, its magnitude is passively determined in the heat transfer element 606 based on the magnitudes and/or temperatures of the flows F_e, F_r and F_o according to predefined criteria, for example for maximizing the COP of the apparatus under prevailing flow and temperature conditions. There may be mechanical passively moving members in the element 606 for adjusting F_{ro} or the desired adjusting can be achieved only by dimensioning of the flow channels within the element 606. Thus, the heat transfer element 606 may act as an entirely passive efficiency control unit.

[0051] The flow channels of the heat transfer element are preferably separated by metal plates, and may operate according to the parallel-flow or cross-flow principle or a combination of these. The heat transfer element may for example form an octahedron, such as a cube filled with the flow channels.

[0052] It has been found that a heat transfer element placed in front of the heat pump unit can increase the COP and tenability of the apparatus significantly in particular in low outside temperature conditions and when at least one of the flows F_r and F_o is active.

[0053] Next, an exemplary control scheme of the apparatus is described.

[0054] Let total target pump flow F_p be equal to X units (e.g. X = 2 m^3/s).

[0055] In a first (classic) state recirculation valve 17A and outdoor air valve 18A are closed, whereby the heat pump flow F_p is formed solely by exhaust air. Thus, F_e and F_d equal to X units and $F_o = F_r = 0$

[0056] In a second (recirculation intensive) state, recirculation valve 17A is opened and oudoor air valve 18A stays closed, whereby F_r equals to y units (y < X; e.g. y = 1 m^3/s) and F_e and F_d equal to X - y units (1 m^3/s). $F_o = 0$.

[0057] In a third (outdoor air intensive) state, recirculation valve 17A is closed and outdoor air valve 18A opened, whereby F_o equals to z units (z < X; e.g. z = 1 m^3/s) and F_e equals to X - z units (1 m^3/s). $F_r = 0$ and F_d = X units (2 m^3/s).

[0058] The control system is designed such that it is able to adjust the state flexibly between the second and third states such that both the recirculation valve 17A and outdoor air valve 18A may be simultaneously open, and $0 < F_r < X$, $0 < F_o < X$ and $F_e + F_r + F_o = F_p = X$. The control system may have certain boundary conditions implemented, such as $F_e > X/4$, or $F_e > X/2$ and/or $F_p > F_{p,min}$, where $F_{p,min}$ is the minimum flow required through the pump. An algorithm running in the control unit takes into account the boundary conditions and measurement data from the apparatus, and determines optimal values for the various flows. Then, the control system drives the apparatus into a corresponding mode of operation, which uses the flows determined.

[0059] According to one embodiment, the control system is adapted to seek the maximum temperature of the total pump flow F_p, by changing the proportions of the exhaust flow F_e, recirculation flow F_r and outdoor air F_o flow. Similarly, if adapted to run in cooling mode, the control system is adapted to seek the minimum temperature of the total pump flow F_p.

Industrial applicability

[0060] The invention is industrially applicable and provides benefits over known systems, as can be understood through theoretical considerations.

[0061] Generally, the mass flow of mixed air through the heat pump is

$$q = q_s + q_u + \beta q$$

[0062] where q_s is the mass flow of indoor air, q_u is the mass flow if outdoor air, and β is the proportion of air that is recirculated. In terms of heat content, this can be written as

$$cqT = cq_sT_s + cq_uT_u + \beta cqT_j$$

where c is the specific heat capacity of air, T the temperature of mixed air, T_s the temperature of indoor air, T_u the temperature of outdoor air and T_j the temperature of discharge air (in Kelvin units). Thus, the temperature of mixed air is

$$T = \frac{q_sT_s + q_uT_u + \beta qT_j}{q}$$

[0063] Assuming that the sum of outdoor air and recirculated air flows is constant, i.e.,

$$q_u + \beta q = k$$

,

it can be shown that

$$T = \frac{q_s T_s + kT_u}{q} + \beta(T_j - T_u)$$

.

[0064] The function $T(\beta)$ is thus linear function with the slope T_j-T_u. If $T_j > T_u$, the function has a maximum at $\beta = 1\text{-}q_s/q$, whereby $q_u = 0$, i.e., the outside air flow is zero. On the other hand, if $T_j < T_u$, the function has maximum at $\beta = 0$, whereby $q_j = 0$, i.e., the circulated air flow is zero.

[0065] Using this simplified model, and assuming that the COP of the heat pump is proportional to the temperature of the air taken in, it can be concluded that the present hybrid apparatus with both outdoor air intake and recirculation allows for choosing optimal mixed air composition in varying circumstances. Thus, with the present apparatus, one can choose a mode of operation, which maximizes the COP of the apparatus.

[0066] One can also estimate a threshold value for the outside temperature, below which it is more beneficial to use recirculated air. With normal indoor air temperature and heat pump performance parameters, it can be estimated that the threshold value is typically between -10°C and 0°C. Such predefined threshold value, together with outside air temperature measurement, can be used by the control algorithm for determining the mixing ratio of outside air and recirculated air.

List of reference numbers

[0067]

10	Exhaust air heat pump (EAHP) apparatus
11	Heat pump
11B	Intake air chamber
11C	Heat pump fan
11D	Seal
12	Circulation chamber
13	First inlet channel for exhaust indoor air
13A	Ventilation channel
13B	Collector chamber
14	Liquid inlet (heating medium)
15	Outlet channel for discharge air (to outdoors)
15A	Discharge valve
15B	Discharge chamber
15C	Weather shield
16	Liquid outlet (heating medium)
17	Recirculation channel
17A	Recirculation valve
17B	Recirculation channel
17C	Recirculation air grate
18	Inlet channel for outdoor air
18A	Outdoor air intake valve
18B	Outdoor air intake chamber
18C	Weather shield
19	Heat recovery heat flow
22	Mixing zone
40	EAHP apparatus
41	Building
42	Apartment/room ventilation channel
43	Collector ventilation channel
44	Exhaust air flow
47	Discharge air flow
48	Replacement air flow
49	Apartment / room
101	Exhaust fan
103	Mixing chamber
105	Temperature evening mesh assembly
105A-D	Temperature evening mesh
109	Insulation
111	Connectors for liquid circuit
606	Heat transfer element
F_e	Exhaust air flow
F_o	Outdoor intake air flow
F_r	Recirculation flow
F_r	Recirculation outlet flow
F_p	Heat pump air flow
F_d	Discharge air flow

Claims

1. An exhaust air heat pump apparatus (10, 40), comprising

   - a first inlet channel (13) for exhaust indoor air,
   - an outlet channel (15) for discharge air,
   - a heat pump unit (11) comprising an air intake connected to the first inlet channel (13) and air output connected to the outlet channel (15), the heat pump unit (11) being capable of recovering heat from or transferring heat to air provided to said air intake, whereby said discharge air is produced at the air output,

   characterized in that the apparatus further comprises

   - a second inlet channel (18) for outdoor air, the second inlet channel (18) being connected to the air intake of the heat pump unit (11),
   - a recirculation channel (17) capable of recirculating part of air at the output of the heat pump unit (11) back to the air intake of the heat pump unit (11),

   wherein the apparatus is adapted to mix said outdoor air, said recirculated air or both said outdoor air and said recirculated air with said exhaust indoor air before feeding to the heat pump unit (11).

2. The apparatus according to claim 1, **characterized by** comprising means for adjusting mixing ratio of said exhaust indoor air, said outdoor air and said recirculated air.

3. The apparatus according to claim 2, **characterized in that** the recirculation channel (17) comprises a first adjustable valve (17A) for controlling the amount of air recirculated to the air intake of the heat pump unit (11) and a second adjustable valve (18A) for controlling the amount of outdoor air provided to the intake of the heat pump unit (11).

4. The apparatus according to claim 3, **characterized by** comprising a control unit functionally connected to said first and second adjustable valves (17A, 18A), the control unit being capable to drive the apparatus selectively into a first mode of operation, where only outdoor air is mixed with exhaust air, and into a second mode of operation, where only recirculated air is mixed with exhaust air, and optionally into a third mode of operation, where both outdoor air and recirculated are mixed with exhaust air before feeding to the heat pump unit (11).

5. The apparatus according to any of claims 3 - 4, **characterized by** comprising

- one or more temperature and/or air flow sensors associated with said first inlet channel (13), second inlet channel (18) and/or said recirculation channel (17) and
- a control unit adapted to control the first and second adjustable valves (17A, 18A) based on measurement data provided by said one or more sensors.

6. The apparatus according to any of the preceding claims, **characterized by** comprising a mixing chamber (103) upstream of the heat pump unit (11), whereby the first and second inlet channels (13, 18) and the recirculation channel (17) are connected to the mixing chamber (22) for carrying out said mixing.

7. The apparatus according to claim 6, **characterized in that** the mixing chamber (103) comprises at least one mesh (105A-D) of metal through which the air is adapted to flow for evening the temperature of air flow fed to the intake of the heat pump unit (11).

8. The apparatus according to any of the preceding claims, **characterized by** comprising a heat transfer element (606) placed upstream of the heat pump unit (11), the heat transfer element (606) being arranged to transfer heat between recirculated air, exhaust indoor air, and optionally outdoor air, before mixing the same for feeding to the heat pump unit (11), the heat transfer element preferably comprising a branch outlet for the recirculated air.

9. The apparatus according to any of the preceding claims, **characterized in that** it is adapted, in at least one mode of operation, to mix outdoor air and/or recirculated air to the mixed air flow such that at least 5 %, for example 5...50% of the mixed air flow comprises outdoor air and/or recirculated air, in terms of volume flows.

10. The apparatus according to any of the preceding claims, **characterized by** comprising means for freely adjusting the mixing ratio of outdoor air and recirculated air.

11. The apparatus according to any of the preceding claims, **characterized by** being a decentralized replacement air exhaust air heat pump apparatus, wherein the heat pump unit (11) is adapted to recover said heat to or transferring said heat from a liquid circuit connectable to heat distribution system of a building.

12. The apparatus according to any of the preceding claims, **characterized in that** said heat pump unit (11) is provided with one or more heat pump fans (11C) for conveying air through the heat pump unit (11), and wherein said recirculation of air through the air recirculation channel (17) is adapted to occur solely due to air pressure caused by said heat pump fan(s) (11C).

13. A method of processing exhaust air of a building (41), the method comprising

- exhausting air from the building to an air mixing zone (22),
- feeding air from the air mixing zone (22) through a heat pump (11) comprising an air intake and an air output and being adapted to recover heat from or transferring heat to air provided to the intake and to provide cooled or heated air at the output of the heat pump (11),

characterized by

- feeding outdoor air to the air mixing zone (22),
- recirculating a portion of the cooled or heated air back to the mixing zone (22),
- mixing the outdoor air and the recirculated air with the exhausted air in said mixing zone (22) before feeding the mixed air to the heat pump (11).

14. The method according to claims 13, **characterized in that**

- said exhausting comprises collecting air from at least ten different rooms (49) of the building (41), and
- providing at least part of replacement air to said rooms (49) via decentralized replacement air channels, and

- recovering said heat to or transferring said heat from a heating water or domestic water reservoir of the building.

15. The method according to any of claims 13 - 14, **characterized by** using an exhaust air heat pump apparatus (10, 40) according to any of claims 1 - 12.

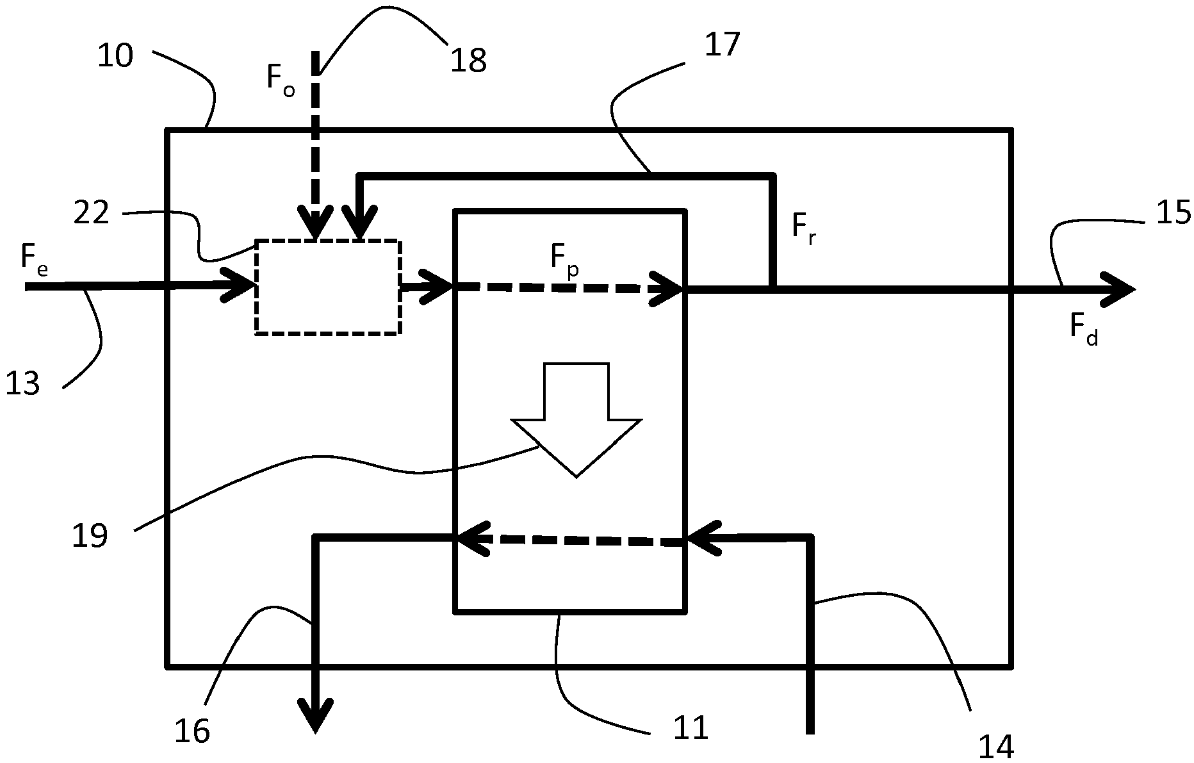

Fig. 1

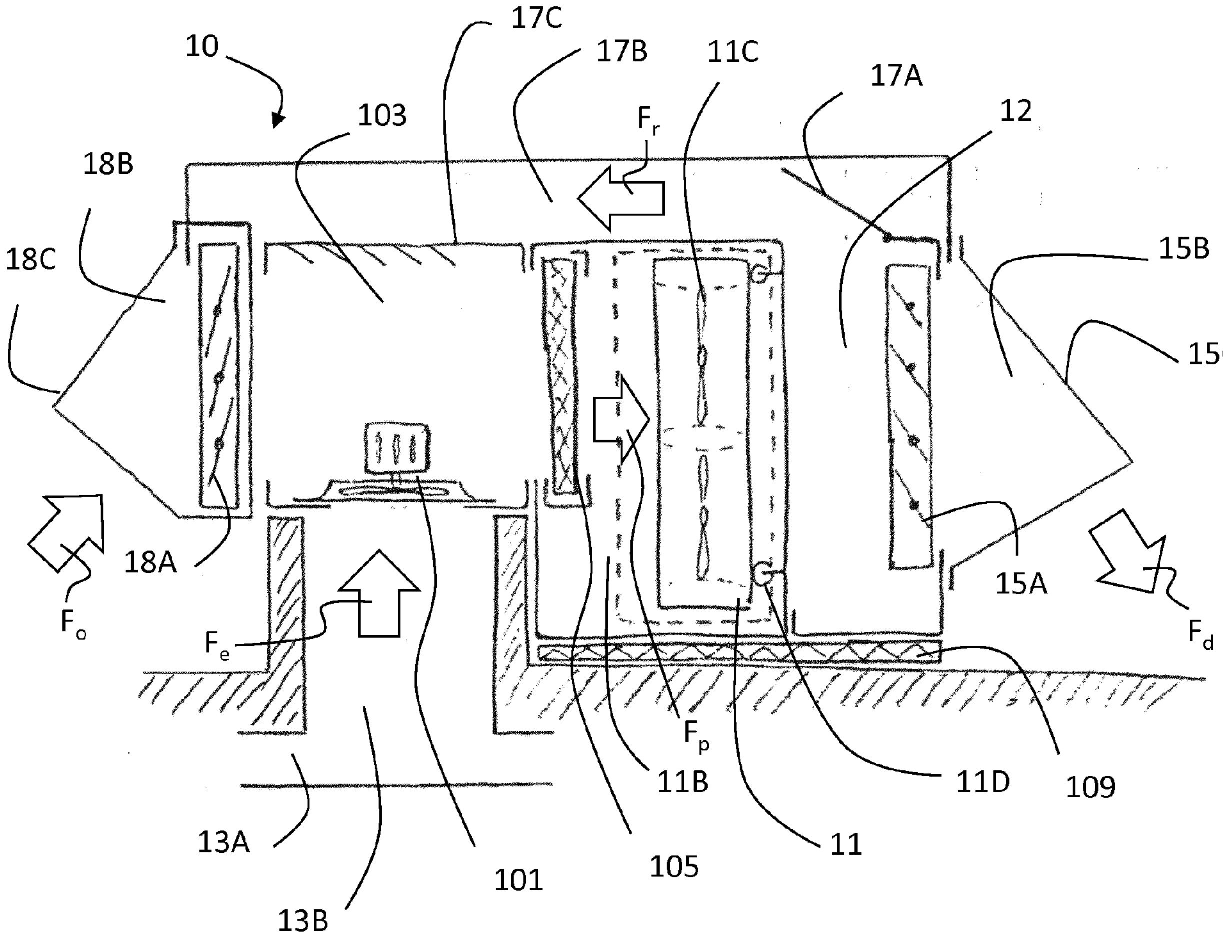
10
17C
17B
11C
17A
12
103
F_r
18B
18C
15B
15C
18A
15A
F_o
F_e
F_d
F_p
11B
11D
109
13A
101
105
11
13B

Fig. 2A

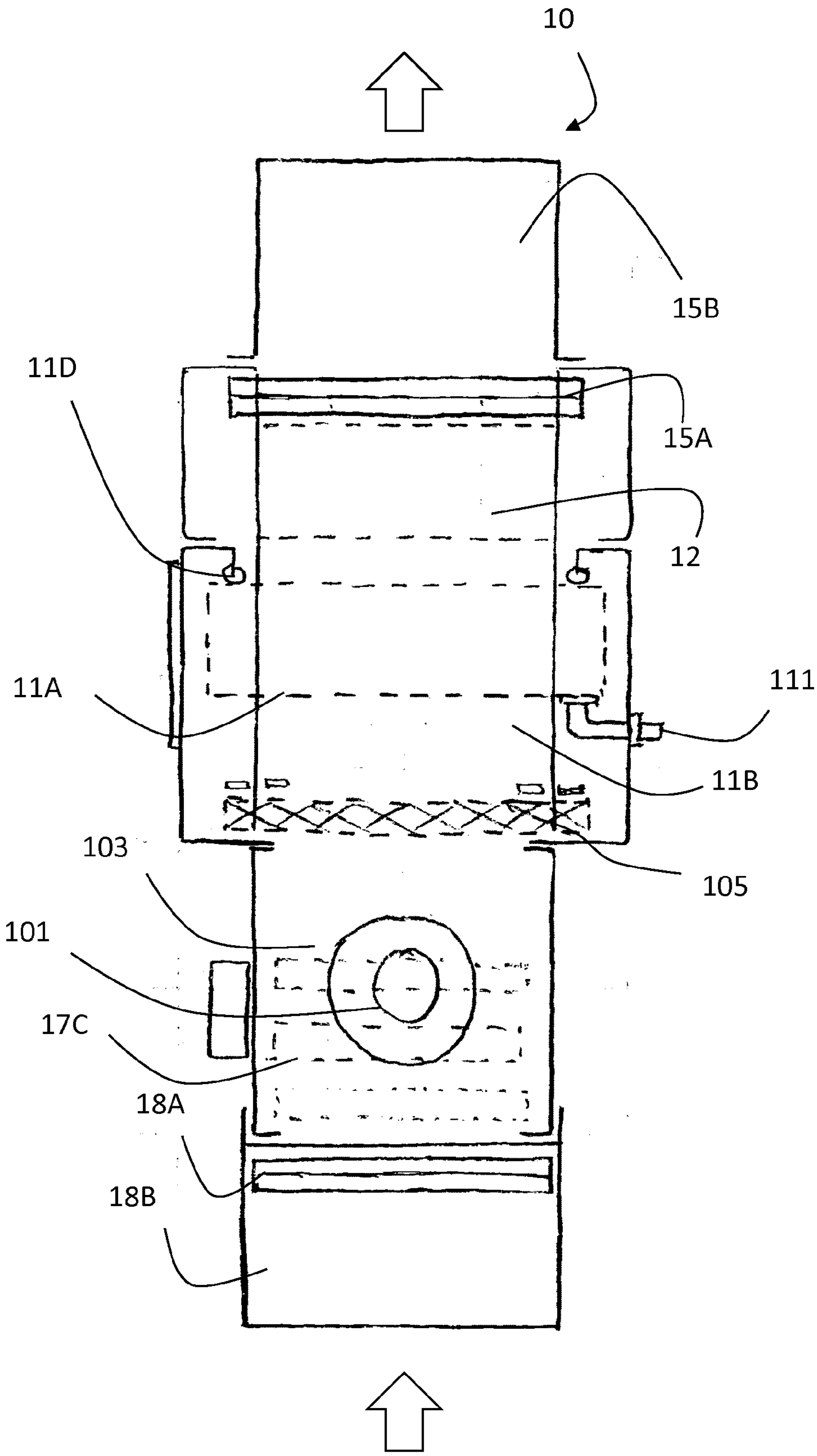

Fig. 2B

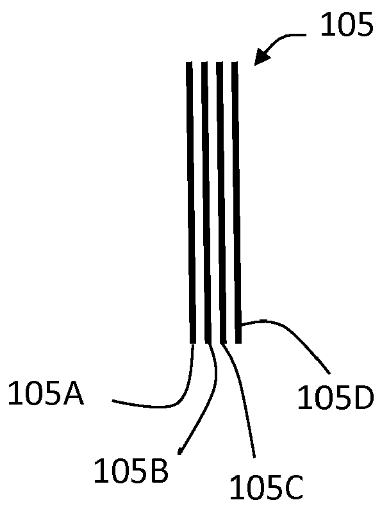

Fig. 3A

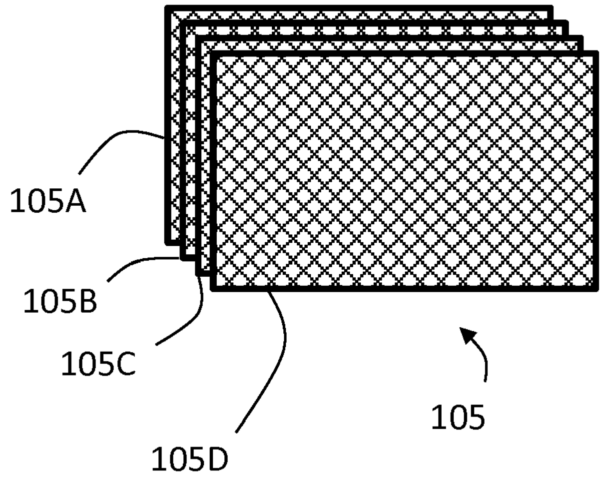

Fig. 3B

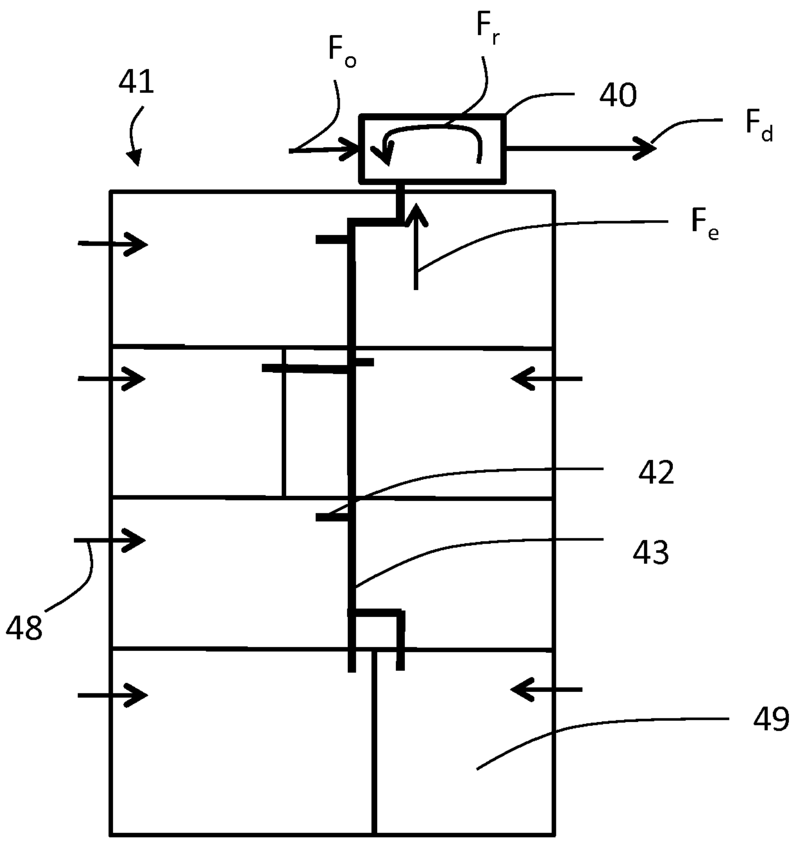

Fig. 4

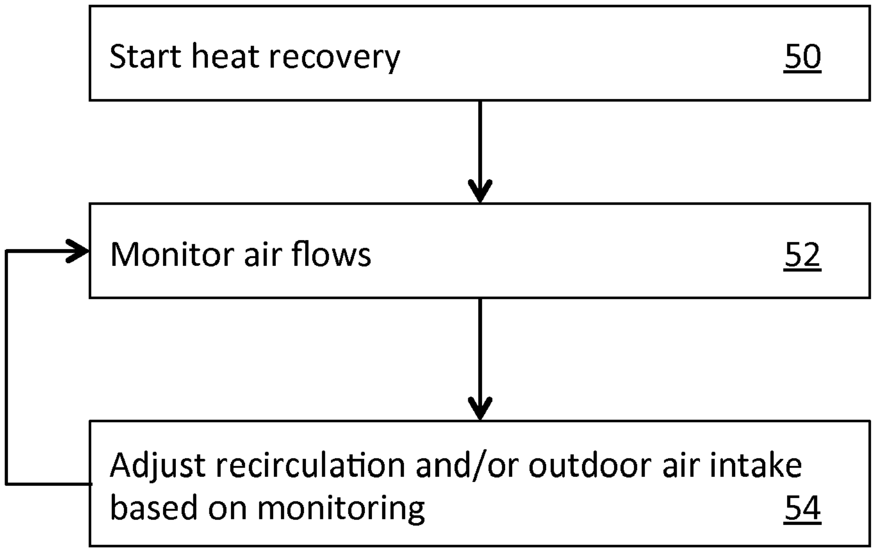
Start heat recovery 50
Monitor air flows 52
Adjust recirculation and/or outdoor air intake based on monitoring 54

Fig. 5

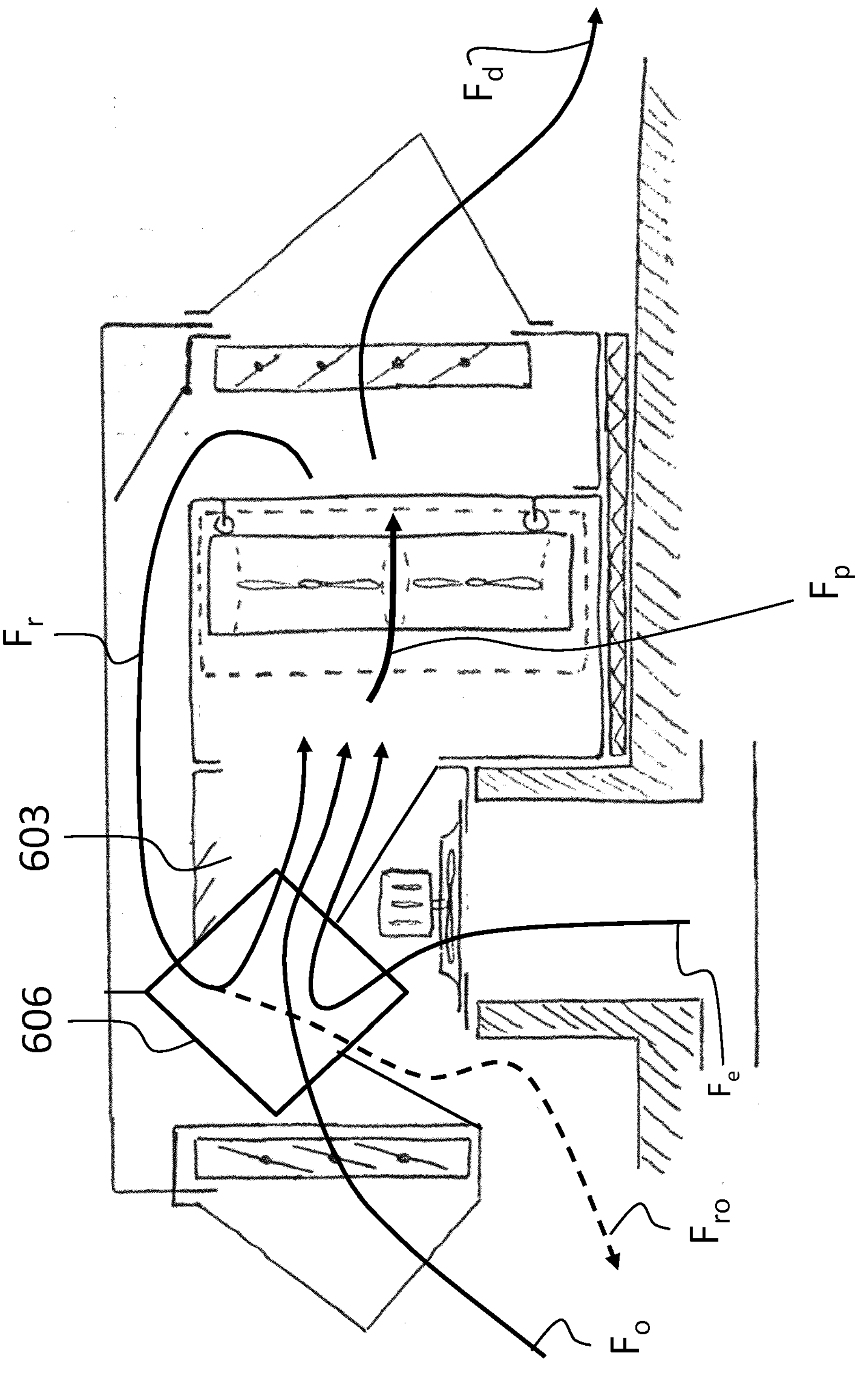

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 17 19 0349

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F24D
F24F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	3 January 2018	Ast, Gabor

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03-01-2018

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